I. C. 6487

MAY, 1931

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

A NEW SIGNALING DEVICE FOR SHAFT MINES WITH COMMENTS AND SUGGESTED MODIFICATIONS

RECEIVED
JUN 15 1931
O. S. U. LIBRARY

BY

L. D. STEWART AND E. V. POTTER, JR.

I.C. 6487,
May, 1931.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

A NEW SIGNALING DEVICE FOR SHAFT MINES[1]

By L. D. Stewart[2]

DESCRIPTION OF SIGNALING SYSTEM

The main reasons for developing an induction system for signaling from the cage are, first, to increase safety, and second, to effect economies in the operation of cage and skip hoists, especially when work is being done in the shaft.

To-day nearly all mines which employ safe methods have installed safety gates on cages, at the different levels, and at the collar of the shaft. Under the old system in some instances signals could only be given from the station outside the cage, and in other cases, after the signal was given the only method whereby those riding on the cage could control its movements consisted of pulling the bell-rope hanging in the shaft, an uncertain and somewhat hazardous procedure at best. With the system herein described, however, it is possible, without opening the gates, to signal to the engineer from any place in the shaft whether or not the cage is moving, and under the same conditions it is possible to converse with the engineer by using the telephone. In short, the cage tender has at all times an opportunity either to signal or talk to the engineer without leaving the cage.

Another added feature is the safety switch connected with the rope in the bonnet of the cage. This switch is normally open but closes and automatically gives the stop signal whenever the rope slackens, which is a decided benefit if the cage becomes stalled in the shaft when being lowered.

---

[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6487."

[2] Electrical engineer, Oglebay-Norton & Co.

The system is very flexible, since as many signal switches can be installed as desired. There can be switches on each deck, and by installation on the top deck of an ordinary receptacle using a plug and switch the switch can be carried outside of the cage to the bonnet while work is being done in the shaft on top of the bonnet.

Two loud speakers are installed in the engine house, the cage loud speaker, which is always in service, and the skip speaker, in service as required. The latter is for use when there is only one hoisting engineer (as on Sundays), or when work is being done in the shaft with the skips and cages together. Either the cage or the skip can be moved by the proper signal.

Regular maintenance of a system of this kind, if installed according to instructions, is very inexpensive, as the only batteries used are on the cage and the telephone circuits, and the current is very light. Consequently a set of batteries should easily last a year. It may be necessary to replace a few tubes on the amplifier during a like period.

The equipment itself is of a type that has no working parts except the vibrator on the code-signal device in the cage, which should give very little trouble.

There has been a great need for signaling device that could be operated from the cage, and several successful systems have been developed. None is as complete as this, however, which is believed to be the only one with a talking circuit - a feature that in itself is a great advance over the service offered by all earlier signaling systems.

Some of the equipment that is involved has been developed especially for this system. The circuit and equipment, shown in Figure 1, are the result of over eight months continuous testing. There is nothing complicated about this circuit, and it can be installed by any mine electrician using the precautions outlined.

INSTRUCTIONS FOR INSTALLING SAFETY CAGE-SIGNAL SYSTEM

An installation of this kind which was tested for six to eight months (see figure 1) revealed a number of factors that had to be considered before satisfactory operation under mining conditions was possible. However, the writer believes that all these matters have been adjusted and that the system may be termed a success.

To begin with, insulation is a factor that can not be overlooked, especially on the aerials on the cage and on the high-voltage wire leading from the code signal to and including the aerial. The high-voltage wire,

Original from THE OHIO STATE UNIVERSITY

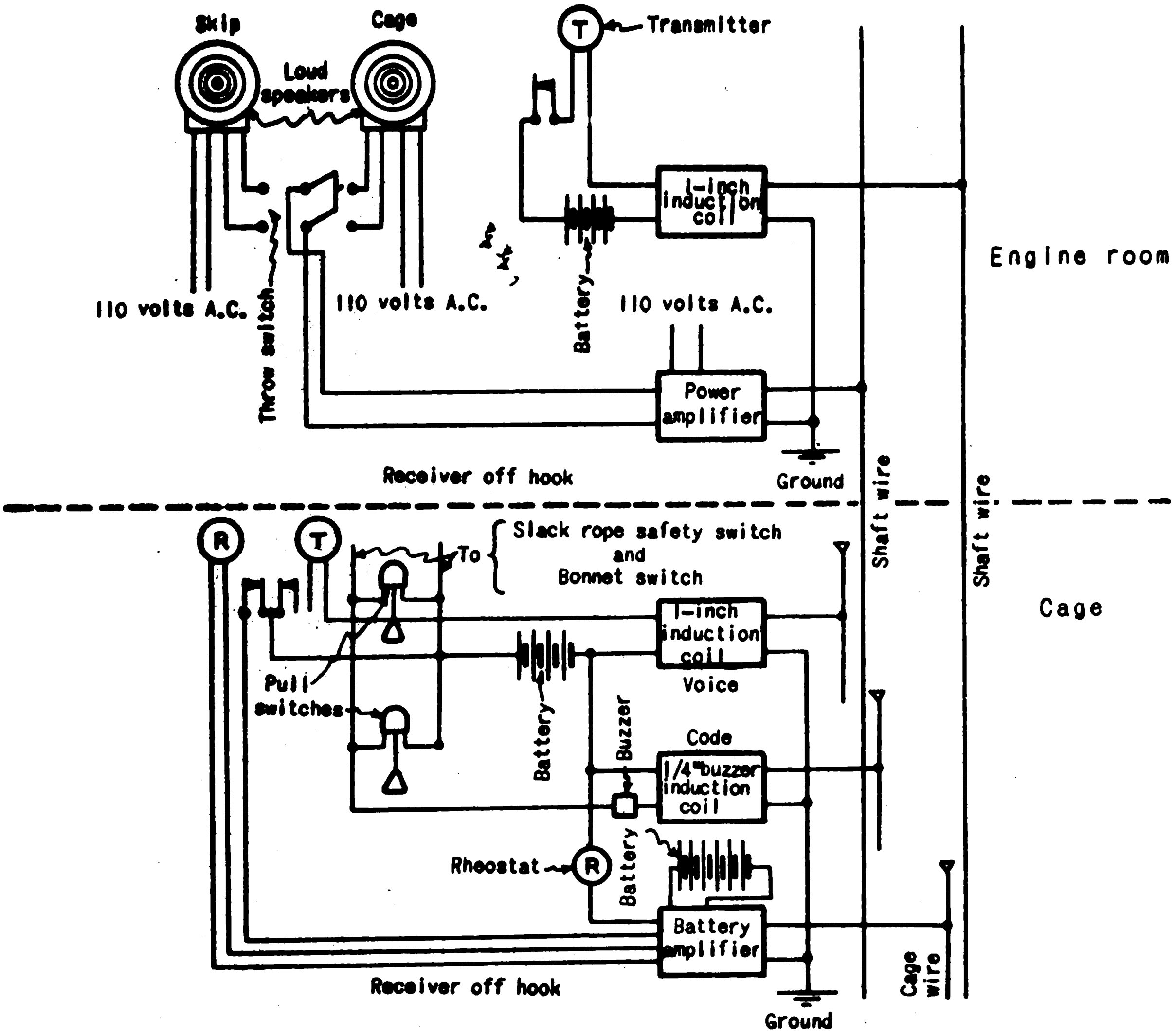


Figure 1.- Engine-room and cage connections as now installed

if not insulated properly, is apt to break down and cause at least part failure of the system. As operation of this system depends entirely upon induction, care must be taken to prevent the occurrence of any undesired inductive effects within the circuit.

In the complete system with facilities for voice transmission both ways and for code signaling one way, a transmitting wire and a receiving wire are required, and they must parallel each other the length of the shaft. To cut down the induction between these two wires and thus avoid feed-back currents, the wires must be placed as far apart as possible; satisfactory operation, however, can be had at a separation of 2 feet. The illustration, Figure 1, shows the circuit.

The writer has found that the receiver can be connected on the amplifier without getting too great a volume by hooking the receiver circuit across the line between the transformer and the speaker coils in the speaker, and by using a 0.03-microfarad condenser in series with the receiver. This receiver circuit goes through the switch hook, and both transmitter and receiver are cut out when the telephone is not in use. Instead of using a double-throw switch to throw on either speaker it is thought best to keep the cage speaker cut in at all times, with a switch on the skip speaker by means of which it may be cut in or out as desired. Speakers are installed both on the cage and on the skip for reasons of safety and added convenience, since by means of a prearranged signal either cage or skip can be moved when work is being done in the shaft.

The speaker may be installed 8 or 10 feet from the telephone on the cage platform, since there is plenty of signal strength for the speaker signal to be heard at a much greater distance.

On the cage a 1½-volt battery in the switch-hook circuit is included to light the lamps on the amplifier whenever the receiver is taken off the hook. The signal switches on the cage can be as numerous as required, because all bridge the line.

An ordinary receptacle is employed in the top deck to receive an extension cord for use on the bonnet any time work may be necessary; a switch, of a type that is normally open, is fastened to the end rope in such a way as to make contact in the event of rope slackening, thereby giving the stop signal.

Digitized by Google Original from THE OHIO STATE UNIVERSITY

The aerial on the cage should be as long as possible, and the closer it parallels the shaft wire the better will be the signal strength. One wire is used in the shaft to include the talking circuit of transmission and the code circuit of transmission. The other wire in the shaft is used for the receiving circuit on voice. All wires should carry a good grade of rubber insulation, especially the aerial wires and circuit on the cage. Circuits devised by the author are working perfectly with a separation of 3 inches between aerial wires on the cage and the shaft wire, which allows for side movement of the cage and is close enough for first-class transmission

A list of the equipment is attached, with the approximate price and address of the manufacturers. If this equipment is installed properly, with care as to the above suggestions, the maintenance cost for the system should be very low and the service far superior to that given by any signaling device now in service. This system has been found very economical, especially where there is work to be done in the shaft. It is applicable to any type of shaft, whether inclined or vertical, except that in an inclined shaft, of course, more hangers will have to be installed to prevent sag; the carrying capacity for the wires in the shaft can be neglected, but sufficient mechanical strength and insulation are necessary.

The type of supports used for the wire in the shaft depends entirely upon the shaft itself and conditions therein. In the shafts sunk during recent years, most of which are vertical, ordinary side-supported trolley hangers make good supports. In the case of shafts equipped with steel sets, the hangers should be hung within the H section of the steel, with a special piece bent in ell shape and connected to the hanger by a long nut so that the clamp will clear the steel on the outside; this type of support proves efficient and need not be placed at more frequent intervals than once in a hundred feet. Installations known to the writer use No. 6 rubber-covered, braided, hard-drawn copper wire. The receiving and transmitting wires should be brought to the cage or engine-room equipment from opposite sides, if practical, and should be kept as far apart as possible.

LIST OF EQUIPMENT

Engine room:

Westinghouse Electric Supply Co., Milwaukee

1 - 37-50 Webster amplifier		$100.00
1 - 0.03-microfarad condenser		.50
2 - 227, 2 - 250, 2 - 281 tubes		25.00
1 or 2 - No. 411 Magnovox dynamic chassi		17.00

Graybar Electric Co., Inc., 500 S. Clinton St., Chicago

1 - No. 1016 C-H cradle hand set		14.00
4 conductor cords to hand set		
6 conductor cords from stand		

Central Scientific Co., 416 E. Ohio St., Chicago

1 - No. F-3683 induction coil		10.00

Cage:

Westinghouse Electric Supply Co., Milwaukee

1 - special Webster 2-stage battery amplifier		25.00
2 - 230 tubes		5.00
1 - 90-volt B battery, small		1.70
6 - dry cells		1.50
1 - No. 51 Jeff. spark coil		3.00
Crouse-Hinds AF 10 galvanized condulet mine-signal switch	each	8.00

Central Scientific Co., 416 E. Ohio St., Chicago

1 - No. F-3683 induction coil		10.00

Graybar Electric Co., Inc., 500 S. Clinton St., Chicago

1 - No. 1016 C-H cradle hand set		14.00
4 conductor cords to hand set		
6 conductor cords from stand		

Ohio Brass Co., Mansfield, Ohio

Trolley hangers and clamps	each	1.00
No. 6 hard-drawn R. C. wire		
		$235.00

COMMENTS AND SUGGESTED MODIFICATIONS

By E. V. Potter, jr.[3]

The system described by Stewart uses the electrostatic capacity between two wires, the shaft wire and cage wire, as the coupling between the apparatus in the cage and in the engine room. This feature of the system makes it necessary to use high voltages, good insulation, and wide separation of shaft wires, so that the energy transferred through the capacity coupling will be sufficient to actuate the receiver and avoid interference. To utilize further the amounts of energy transferred from one system to the other sufficiently for it to actuate the telephone receiver or the loud speakers, amplifiers such as are shown in the diagram must be used. The apparatus which would be required for such a system may be described as follows.

ENGINE-ROOM EQUIPMENT

For the apparatus in the engine room five units are needed: (1) The loud speakers, (2) the power amplifier, (3) the transmitter microphone, (4) the battery, and (5) the induction coil. Of these the transmitter, battery, and induction coil will be considered first, as they are the same regardless of the power supply used for the rest of the equipment. The transmitter is a carbon-type microphone, that is, an ordinary telephone transmitter. The induction coil, or transformer, has low direct-current primary resistance, about 20 ohms, and an inductance of about 0.1 henry. The secondary should have a large number of turns, so the output voltage impressed on the shaft wire will be high. The higher the step-up ratio of the transformer the better the system will operate. A 6-volt battery is used to actuate the transmitter, the current used on normal operation being 0.05 to 0.1 ampere. If the transformer has a higher direct-current resistance than the one described, above the battery voltage should be increased to keep the current at about 0.05 to 0.1 ampere.

POWER AMPLIFIER

Considering the power amplifier and loud speakers, two types are available, depending on the nature of power supply at the particular location. Where an alternating-current supply is available the amplifier may be operated directly from the power-supply lines, and dynamic speakers may be used. The field current for energizing the speakers also may be taken from the A.C. supply. Such an amplifier will be described in detail later. In this system the essential feature is that the input transformer must have a high impedance primary, due to the high coupling

---

[3] Junior engineer, U. S. Bureau of Mines.

Original from THE OHIO STATE UNIVERSITY

impedance inherent in the capacity coupling. If it is more desirable to use dry batteries as a source of power supply for the amplifier and speakers, magnetic speakers instead of the dynamic type preferably should be used. Such an amplifier with the proper speaker is described later. The same requirements in regard to the input transformer must be met, however.

CAGE EQUIPMENT

The apparatus in the cage consists of the receiving equipment, the transmitter, and a buzzer for signaling. The transmitter is almost identical with that used in the engine room. Here, however, the transmitter is connected to the battery through a switch. When the receiver is taken off its hook the switch closes the transmitter battery circuit and closes the filament circuit to the amplifier at the same time. In this way the drain on the batteries supplying the power for the amplifier is kept at a minimum. The "induction coil" used in the transmitter is the same as that in the engine room; a 6-volt battery must be employed, however, since it also supplies power for the buzzer and the filaments of the amplifier. Separate batteries can be used for each unit, but by employing a common battery the equipment in the cage is kept more compact. An ordinary 6-volt buzzer is used, and the induction coil employed with it is similar to that used with the transmitter and may be exactly like it. The primary D. C. resistance should be low also, but the step-up ratio need not be as high as in the case of the telephone transmitter. The receiving amplifier and receiver necessarily are supplied by dry batteries, a 90-volt B battery and a 6-volt A battery. This amplifier is described subsequently. In this case, however, the input transformer must have high primary impedance. The receiver, which may be an ordinary telephone receiver, is connected through a 6 to 1 step-down transformer to the amplifier, the receiver impedance being about 75 ohms. Higher-impedance receivers may be used, and a 2,000-ohm or higher-resistance receiver could be connected to the amplifier through a 1 to 1 transformer.

The system of electric coupling between the shaft wire and the cage used in the plan described by Stewart is its most serious disadvantage. The voltages on the shaft wire and cage wire must be high to get any considerable transfer of energy from the cage to the engine room or vice versa. The description of another system, employing electromagnetic coupling, follows. In this the equipment in the cage is reduced to a minimum, all the amplifiers being put in the engine room, leaving only the buzzer, transmitter, and receiver in the cage.

The essential difference between the two systems, instead of using two single insulated wires which run the full length of the shaft, consists in employing two rubber-insulated wires, supported as described by Stewart, spaced about 2 feet apart, and connected at the bottom, forming a complete loop the center of which is grounded at the bottom of the shaft. Current may pass either down both wires and up through the ground, or up one wire and down the other, depending on whether the voice is transmitted from the cage to the engine room or from the engine room down to the cage. If the voice is going from the cage, the transmitter current passes through a coil on the cage and the magnetic field of this coil induces a voltage pressure on the shaft loop. This voltage may be amplified and the voice reproduced by a loud speaker. If the voice is being transmitted from the engine room to the cage, currents flow in the shaft loop, and the magnetic field of these currents induces voltages in a loop on the cage, where a receiver reproduces the voice. The loops on the cage will be described later. Schematic diagrams of the system are shown in Figure 2 and in Figure 3, for A. C. power supply and for D. C. power supply, respectively.

Consider the equipment for the system employing an A. C. power supply. Transmitter "T" and the battery are, as in the other system, an ordinary phone transmitter and a 6-volt battery. The No. 1 amplifier, the essentials of which are shown in Figure 4, is 3-stage, using A. C. heater tubes in two stages and two power tubes connected in the push-pull in the last stage.

The input transformer has a low impedance and resistance primary, about 20 ohms D. C. resistance and 0.1 henry inductance. This is a 5 to 1 ratio transformer and connects directly to the first amplifier tube. A 2,000-ohm resistance and a 2-mfd. 200-volt condenser in parallel are connected in series with the cathode to get the proper grid bias. The tube connects to a high-impedance transformer of 3.5 to 1 ratio. The transformer goes to the next tube, similar to the first-stage amplifier. The second-stage output now goes through a push-pull input transformer to two UX-245 tubes. The negative bias for these tubes is obtained through a 780-ohm resistance connected from the center of the filament circuit to ground, the B battery being grounded. If necessary a further flexibility in bias is provided in taps on the 20,000-ohm potential divider. A 4-mfd. condenser of 200 volts rating is used to bypass audio-frequency currents. The output uses two equal transformers in series, having high-impedance primaries, and about 6 to 1 step-down ratio with low-resistance secondaries. The filament-supply and plate-voltage supply are obtained from a rectifier unit in the amplifier. This unit has a 110-volt primary transformer of 75-watt capacity, with three secondaries. One has 750 volts, centertapped, and gives 100 milliamperes. The others give 5 volts at 2 amperes for the rectifier filament, this being centertapped, and a 2.5 volt, 6-ampere winding, also centertapped. A UX-280 type rectifier is used. The filter consists of one 2-mfd. and two 4-mfd. condensers rated at 600 volts and two 30-henry inductances with 100-milliampere capacities. This unit gives 300 volts for the UX-245 tubes, and by means of the 20,000-ohm voltage divider tapped at 3,500 ohms, 200 volts is gotten for the UX-227 tubes. The connection to the shaft loop will be discussed later. If heater tubes are used the amplifier must be connected continuously, as the tubes take about 45 seconds to get hot enough to operate. The amplifier and power-supply unit may be incorporated in a single compact unit located near the telephone.

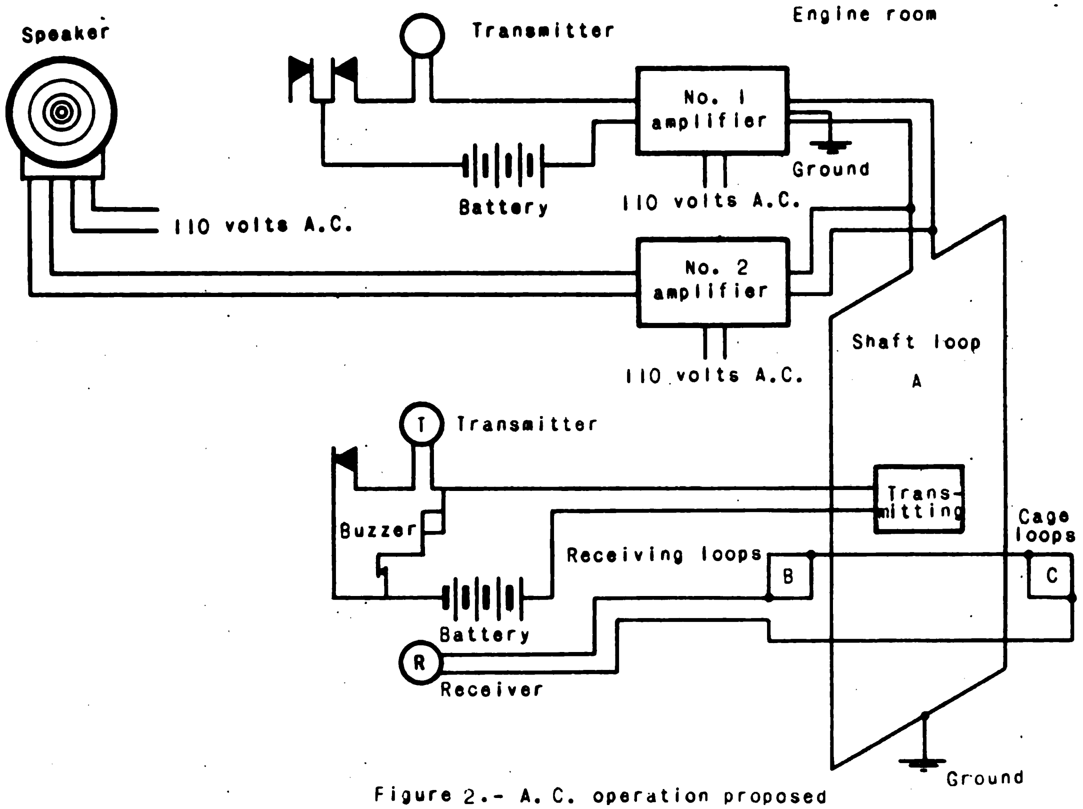
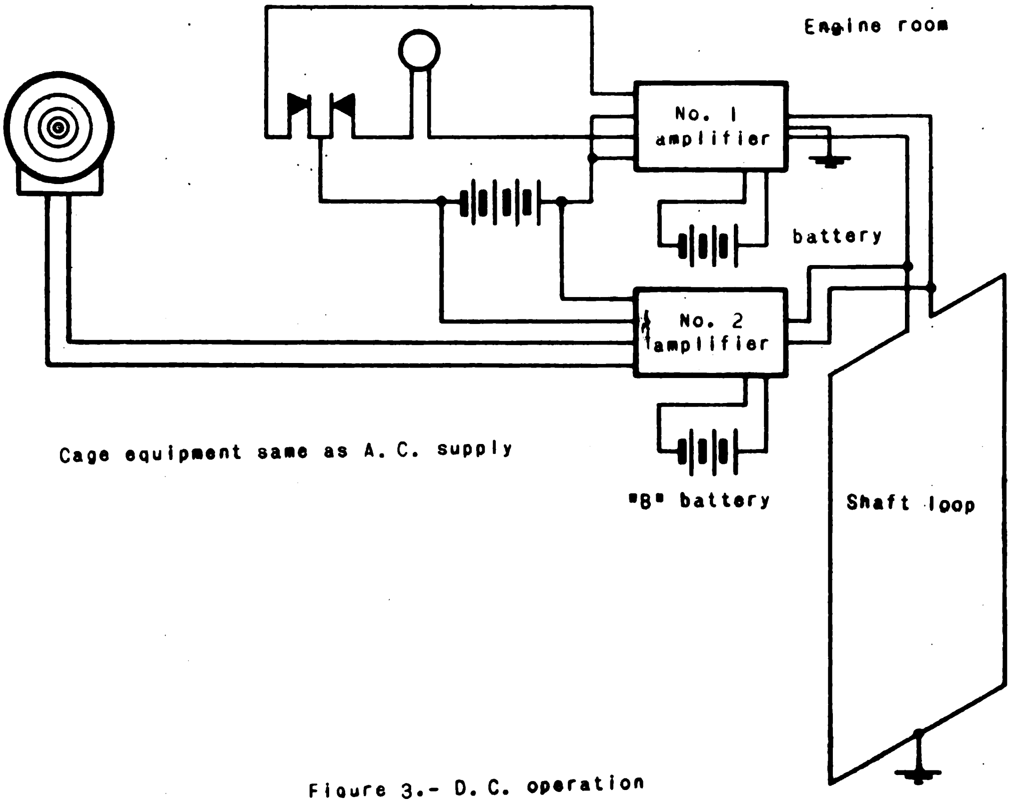


Figure 2.- A. C. operation proposed



Cage equipment same as A. C. supply

Figure 3.- D. C. operation

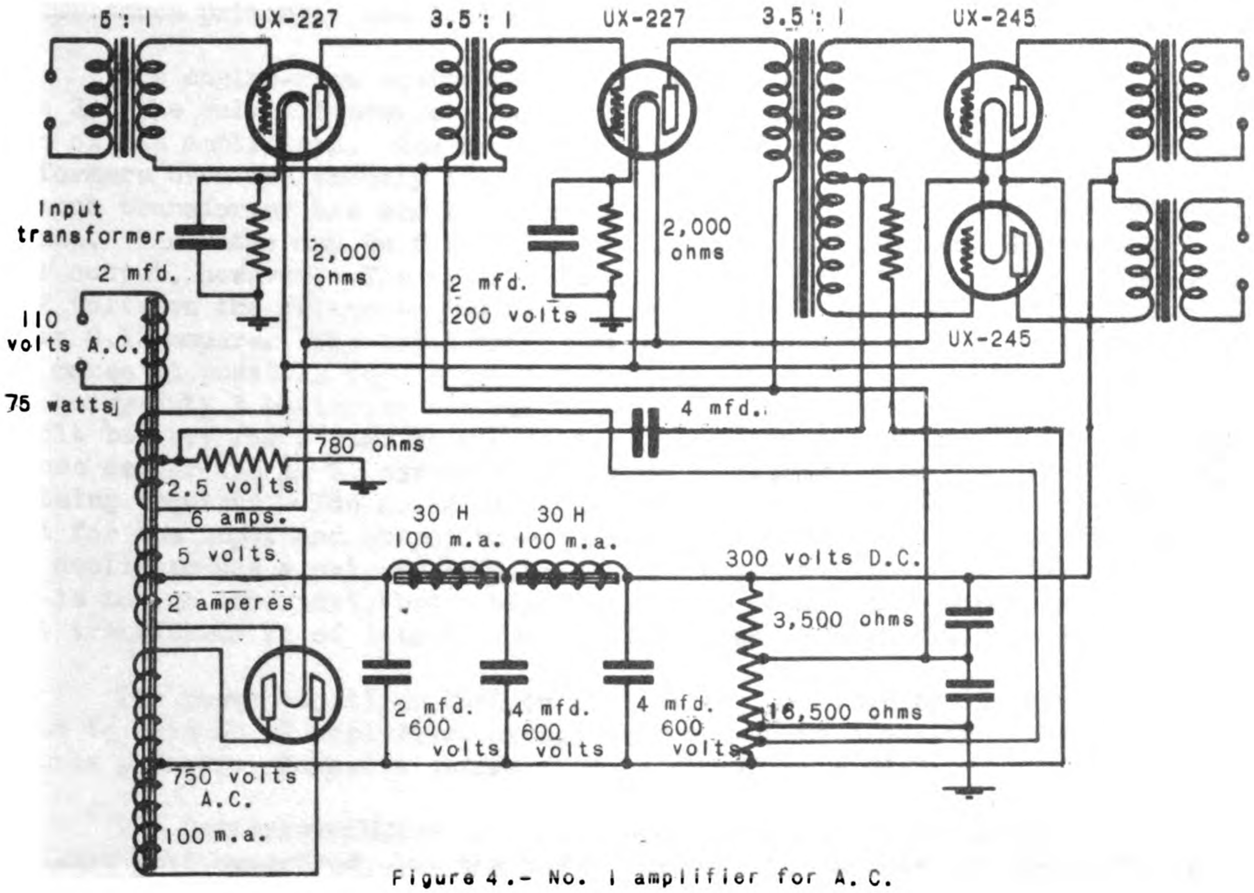


Figure 4.- No. 1 amplifier for A. C.

The No. 2 amplifier is exactly like the No. 1 amplifier just described, except for the input and output transformers. In this case, the input transformer has a primary impedance of about 2 millihenrys. The secondary has a large number of turns to give a high step-up ratio; the actual step-up ratio is not important, however. The output transformer is a single push-pull output type of a 25 to 1 step-down ratio, designed to feed into a dynamic speaker. The speaker field is supplied from the A. C. supply.

The A. C. amplifier used in the system described by Stewart is similar to the No. 2 amplifier, except for the input transformer, which has a high-impedance primary. The loud speaker is also a dynamic speaker.

The engine-room equipment for the D. C.-operated system is shown in Figure 3. The only difference between this and the A. C. equipment is in the design of the amplifiers. The No. 1 amplifier is shown in Figure 5. The transformers used are exactly the same as for the A. C. amplifier, Figure 4. The input transformer has about 20 ohms D. C. resistance and 0.1 henry inductance. The ratio may be 5 to 1 but is not critical; higher ratios give higher output, however. The tubes used are UX-230 and UX-231. The UX-230 uses 2 volts on the filaments and draws 0.06 ampere. The UX-231 uses 2 volts also, at 0.13 ampere. The total drain for this amplifier is only 0.25 ampere, which makes it possible to use two 1.5-volt dry cells to supply the power. Three heavy-duty B batteries are required to supply the plate power and one 22½-volt battery for C bias on the power tubes. The output system is exactly the same as for the A. C. system and will be described later, two transformers also being required. The No. 2 amplifier is just like the No. 1 amplifier, except for the input and output transformers. The input transformer in the No. 2 amplifier has a primary inductance of about 2 millihenrys. The step-up ratio is not so important, but a high ratio will give louder signals. The output transformer is of 1-to-1 type and feeds into a magnetic speaker.

The power amplifier used in the system described by Stewart is similar to this No. 2 amplifier, except that the input transformer has a high-impedance primary. Magnetic speakers are employed here also.

The battery amplifier used in the cage is similar to the D. C. amplifiers just described, but the power required to operate the telephone receiver is not as great as that required by the loud speakers. Figure 6 shows this amplifier. Here a 2-stage amplifier is sufficient, and UX-230 tubes are used in both stages. The input transformer has a high primary impedance, and the ratio may be as high a step-up as is available, the higher ratios giving louder signals. The interstage transformer has a 3.5 to 1 ratio. The output transformer depends on the type of receiver used. With the ordinary telephone receiver it is a 6 to 1 step-down ratio, but up to a 10 to 1 ratio will be satisfactory. With a receiver of 2,000 ohms impedance or higher a 1 to 1 transformer is sufficient. Only two heavy-duty batteries are required, 90 volts being used. Two 1.5-volt dry cells are used for the filaments and a 4.5-volt C battery for the grid bias on the tubes. All these amplifiers may be built conveniently in small cases and require very little room. The connection between the output of the No. 1 amplifier and the shaft loop will now be described.

METHOD OF OPERATION

Consider what happens when someone speaks in the cage. The voice currents flow through loop A, Figure 7, which is on the cage and located symmetrically with respect to the shaft loop wires. The magnetic field of this loop will induce equal voltages in each of the loop wires, and a current, I_c, will flow up one wire and down the other. The ground will have no effect here, as there will be no current flowing into it if the voltages in the two wires are equal. If loop A is nonsymmetrical the voltages will not be equal and current will flow into the ground, but the system will operate, nevertheless. Part of current I_c will flow through the primary of transformer 3 and induce a voltage in the secondary which will pass through the amplifier to the speakers. The other part will pass through the secondaries of the transformers and will be lost. Now consider what happens when someone speaks from the engine room. The voice currents are amplified, and two equal voltages e_1 are induced in the secondaries of transformers 1 and 2. The secondaries are connected so that currents I_s due to these voltages will flow up or down both wires simultaneously and return through the ground. There will not be any current in the primary of transformer 3, however, and thus none of the signals from the engine room will return through amplifier 2 and the speakers in the room. In the cage two small loops B and C are mounted alongside loop A. The magnetic field of the current on each line will induce voltages in the two small loops B and C, and by connecting them in series so that the voltages add to and do not neutralize each other a receiver in series with them will reproduce the signal.

The equipment in the cage is shown in Figure 2. The transmitter is the same as that used in the engine room. A 6-volt buzzer is used with a 6-volt battery. Transmitting loop A is wound on a wooden frame 2 feet square and 1 inch thick and is about 500 turns of No. 20 or 24 wire. With smaller wire more battery voltage must be used. The number of turns of wire required on the coil is indefinite and may best be found by trial, 500 being satisfactory, however. Two receiving loops are used, as indicated at B and C in the figure. Each has about 400 turns of No. 24 wire wound on a square wooden frame 1 foot square and 1 inch thick. No amplifier for receiving signals from the engine room is necessary because of better energy transfer with a magnetic coupling.

The large loop is placed so that it is symmetrical with respect to the shaft wires, two sides being parallel to the two wires and directly opposite them.

The smaller loops are placed in the cage 3 feet apart, center to center, and so that the sides toward each other are opposite the two shaft wires. These coils are connected in series and therefore must be connected so that the voltages in them add and do not oppose each other. This is ascertained by changing them to get the best signal strength in the receiver.

A. C. equipment is more powerful and if possible should always be used. The power required for such equipment is 100 to 150 watts. D. C. equipment should be used conservatively because of the drain upon the dry batteries supplying the set.

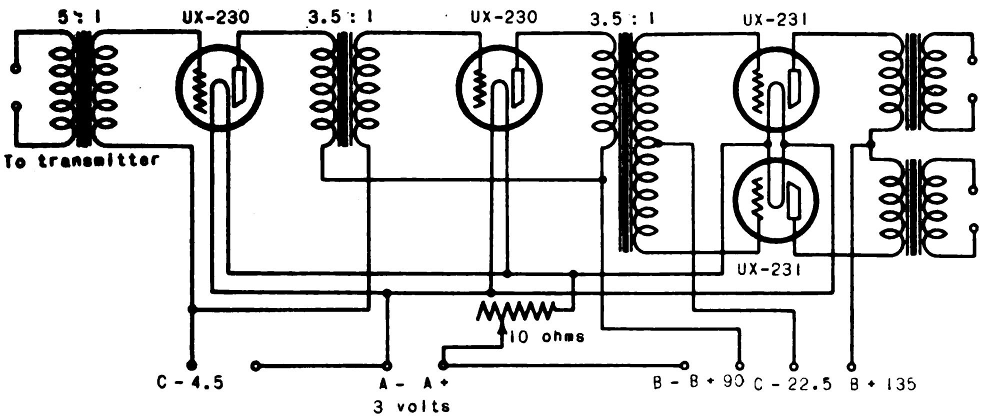


Figure 5.- Amplifier for D.C.

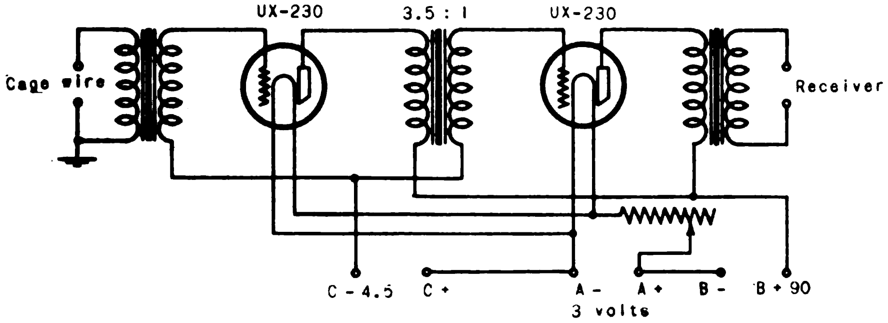


Figure 6.- Cage battery amplifier

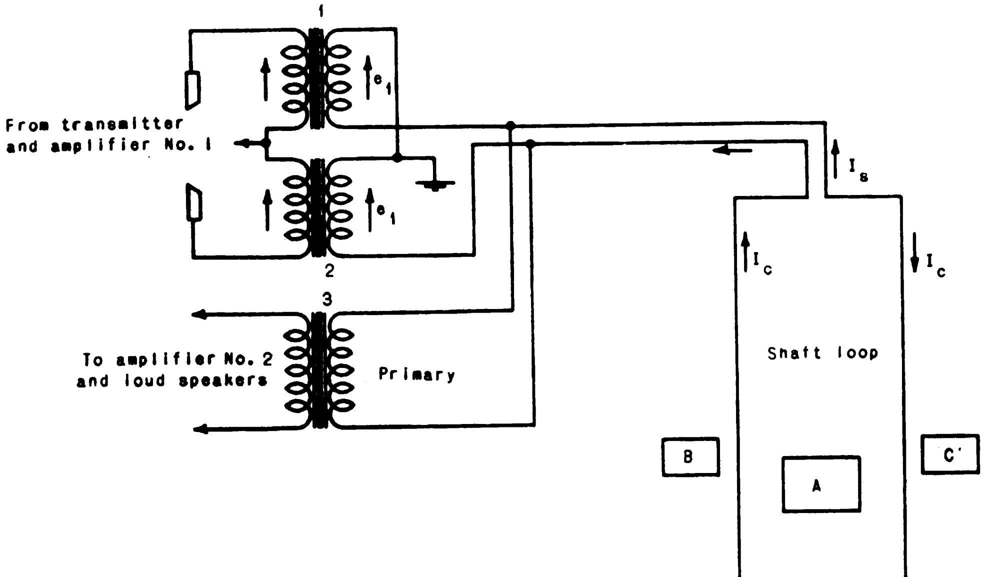


Figure 7.- Showing principle of operation